DEVELOPING MISSION SEGMENT-SPECIFIC CLINICAL DATA FOR IMPACT

Human Research Program
Exploration Medical Capability Element

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"Expanding the Boundaries of Space Medicine and Technology"

Agenda

- Objective
- Background
- Approach
- Challenges & Limitations
- Output
- Lessons Learned

Objective

Defining how different segments may change the IMPACT model for a long duration spaceflight Design Reference Mission (DRM):

- Incidence
- Return to Definitive Care (RTDC)
- Loss of Crew Life (LOCL)

Objective

Not to be considered:

- Operational times:
  - Pre-launch
    - pre-existing conditions related to launch prep
  - Launch operations
- Resource allocation between segments
- Determining how crew physically will move between segments for resources
- Impacts to mission success or alternative models for achieving subsets of the mission

Background

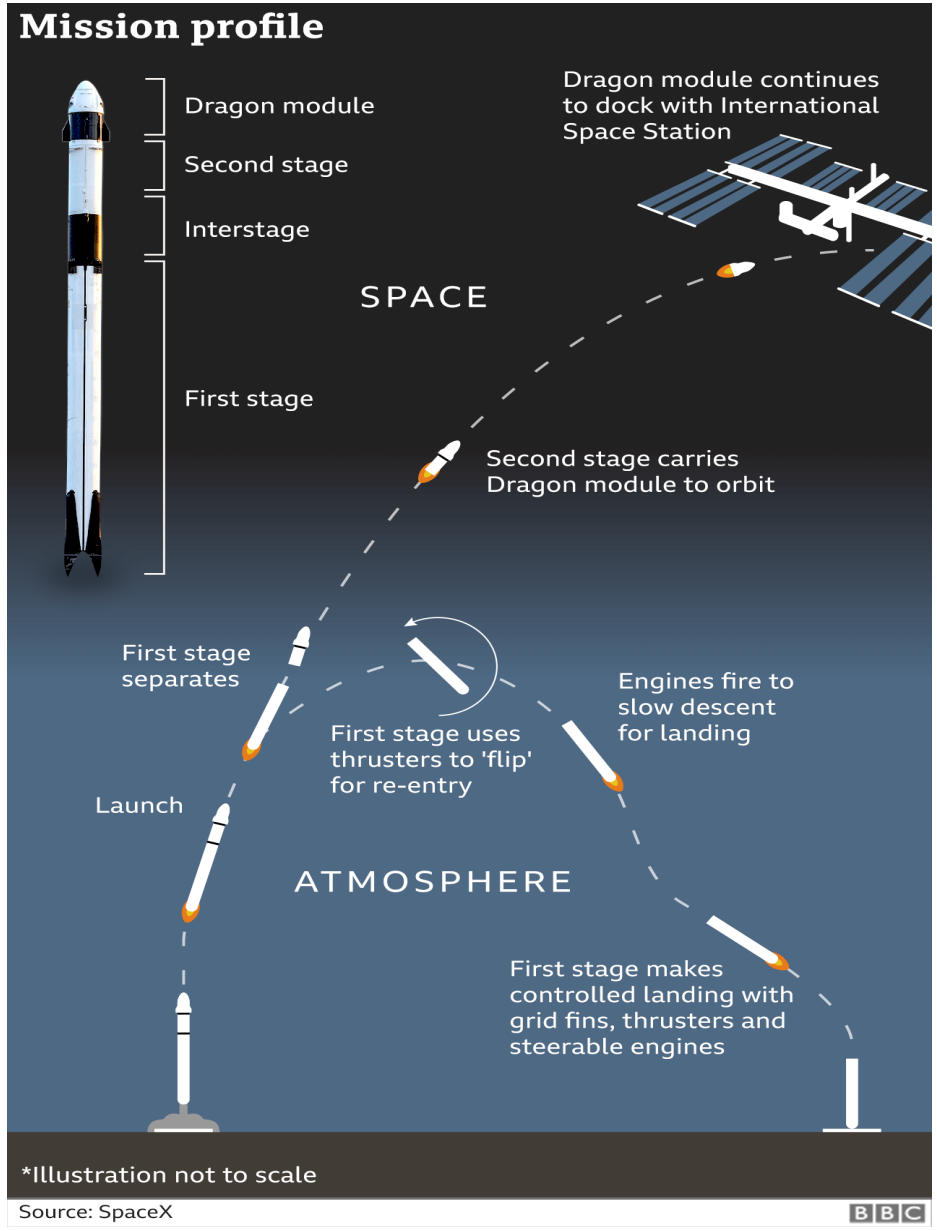
Medical risks are currently assessed using the Integrated Medical Model (IMM) for International Space Station (ISS) Operations

- IMM uses a Probabilistic Risk Analysis/Monte Carlo Simulation to calculate:
  - Medical Events
  - Crew Impairment
  - Loss of Crew Life (LOCL)
  - Evacuation
  - Resources used

Background

ISS Mission Profile:

- The mission profile of an ISS crew involves:
  - Launch
  - Docking
  - Quiescent/Micro-gravity Operations (on board ISS)
  - Undocking
  - Reentry

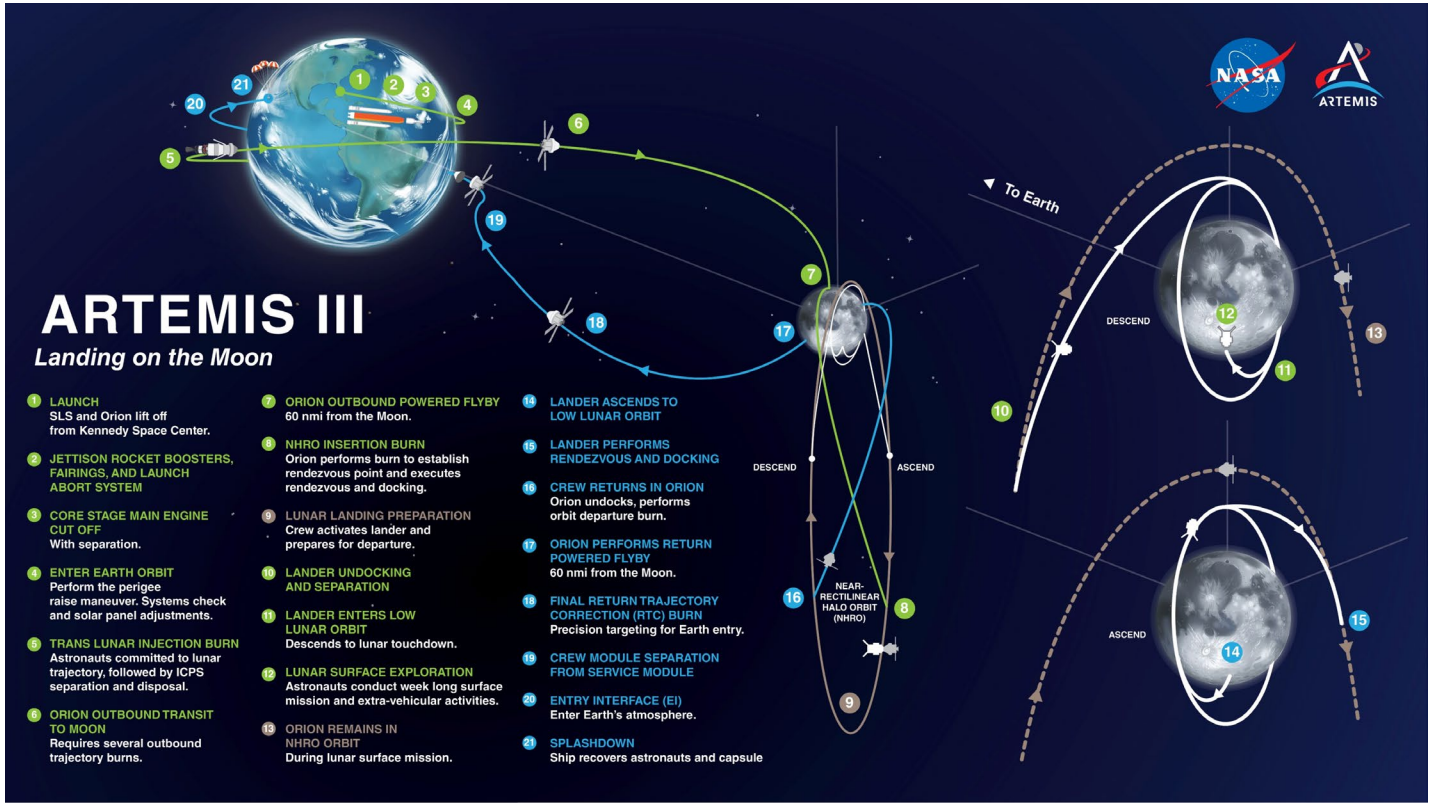


Background

Artemis III Mission Profile:

- The mission profile of an ISS crew involves:
  - Launch
  - Earth Orbit
  - Trans-lunar Injection
  - Quiescent/Micro-gravity Ops
  - Lunar Injection
  - Lunar Orbit
  - Lunar Descent/Landing
  - Lunar Ops
    - Habitat, EVA, Rover

  - Everything above again, reversed…



Background

Space-based Medical Experience

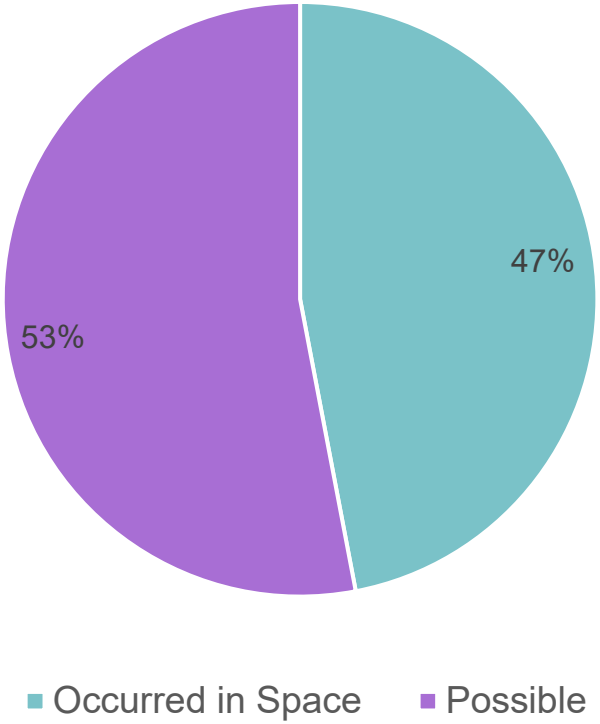
- Crew have 29,000 days (or 77 years) in space including over 100 days of spacewalks
- 622 people from 38 countries have been in space

- That may sound like a lot, but for every second on Earth (assuming 7.88 billion people), there are **249.8 years cumulatively lived** – We do not have a lot of medical experience yet

Background

IMM performed data analysis on missions:

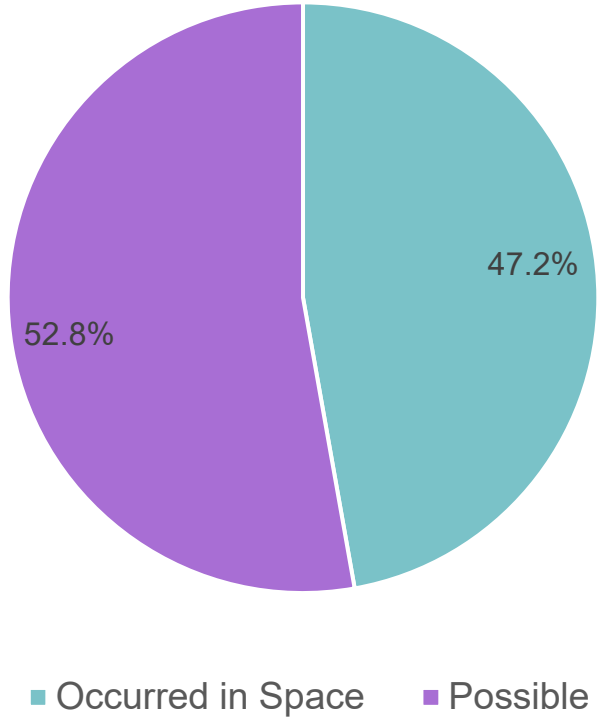
- ISS Expeditions 1 through 13
- STS-01 through STS-114
- Apollo
- Skylab
- Mir



- Covered 100 Medical Conditions and found that 47% had occurred in space with the remaining 53% possible

Background

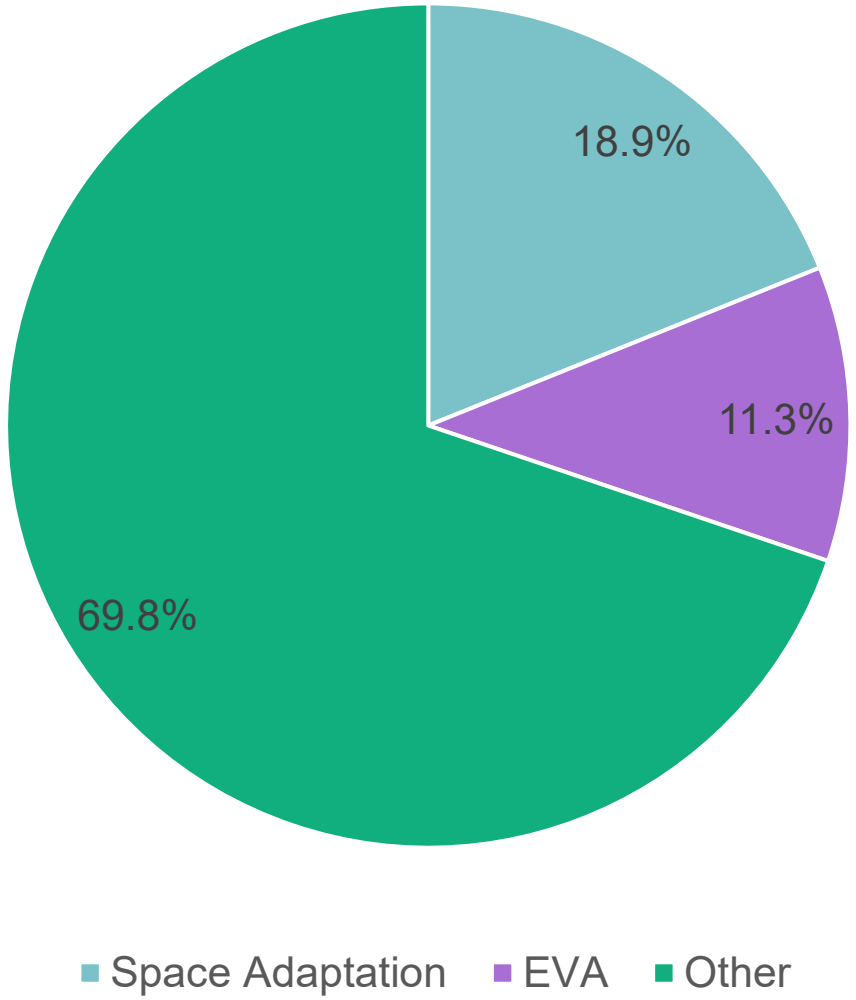
- IMPACT has gathered data from all IMM products and extended the analysis to the present
- Additionally, 23 more medical conditions were added to the Evidence Library



- Stubbornly, despite the additional spaceflight experience, because of the additional medical conditions added, only 47% of conditions have occurred in space…

Background

- Of the conditions (58 total) that have occurred in space 5 were anecdotal occurrences and were NOT used for data incidence analysis, thus leaving only 53, or **43.1%**
- Additionally, 16 (30.2%) are specific to spaceflight (18.9% space adaptation and 11.3% Extravehicular Activity (EVA))



Background

- 43.1% of the 123 medical conditions have occurred sufficiently to be used for incidence calculations in our IMPACT model
  - Of these, 30.2% were spaceflight specific
- Therefore, ground analogous medical conditions that have been sufficiently observed during spaceflight to be used to calculate future incidence represent only **30.1%** (69.8% of 43.1%) of all medical conditions in the Evidence Library.

Approach

Mission Segments Considered:

- Space Adaptation – Specific conditions already defined for this segment
- Micro-gravity – All transit environments regardless of the vehicle (e.g., transit to the moon on Gateway)
- Landing ops – Earth, Lunar, and Martian landing operations (assumption of a “gentle” landing nominally)

Approach

Mission Segments Considered:

- Habitat – Extraterrestrial Surface (ie. gravity) ops (Hab pressures are undefined at this point so both possibilities are considered)
  - Sea-level pressure
  - Low pressure
- Rover (Team assumed that Rover pressures will be either low pressure or EVA suit will be worn, and Rover will not hold pressure)
- EVA
  - Partial Gravity (i.e. outside of Hab)
  - Micro Gravity (i.e. during transit)

Approach

- Evidence Library effort made clear that quantification of risks of medical conditions was difficult when the team considered different gravitational environments
- Team was confident that the existing limited data would not suffice to further quantify risks

Approach

- Rather than assessing only a small subset of conditions (20 by contract, leaving error in choice a concern), our team chose to assess all the ICL conditions

- Created a “qualitative effort” where conditions in the ICL were assessed using medical judgement for changes (increase or decrease) for Incidence, RTDC, and LOCL

Approach

Example:

	Space Adaptation	Microgravity	Landing Ops	Sea Level Hab	Low P Hab	Rover (Low p)	Partial G EVA	Micro G EVA	N
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	Decrease	Decrease	Decrease	Decrease	Decrease	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
SHIP PROBLEMS									
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
ESS									
	N/A	N/A	No Change	N/A	N/A	N/A	N/A	N/A	
	N/A	N/A	No Change	N/A	N/A	N/A	N/A	N/A	
	N/A	N/A	No Change	N/A	N/A	N/A	N/A	N/A	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	
	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	

Challenges & Limitations

Limitations

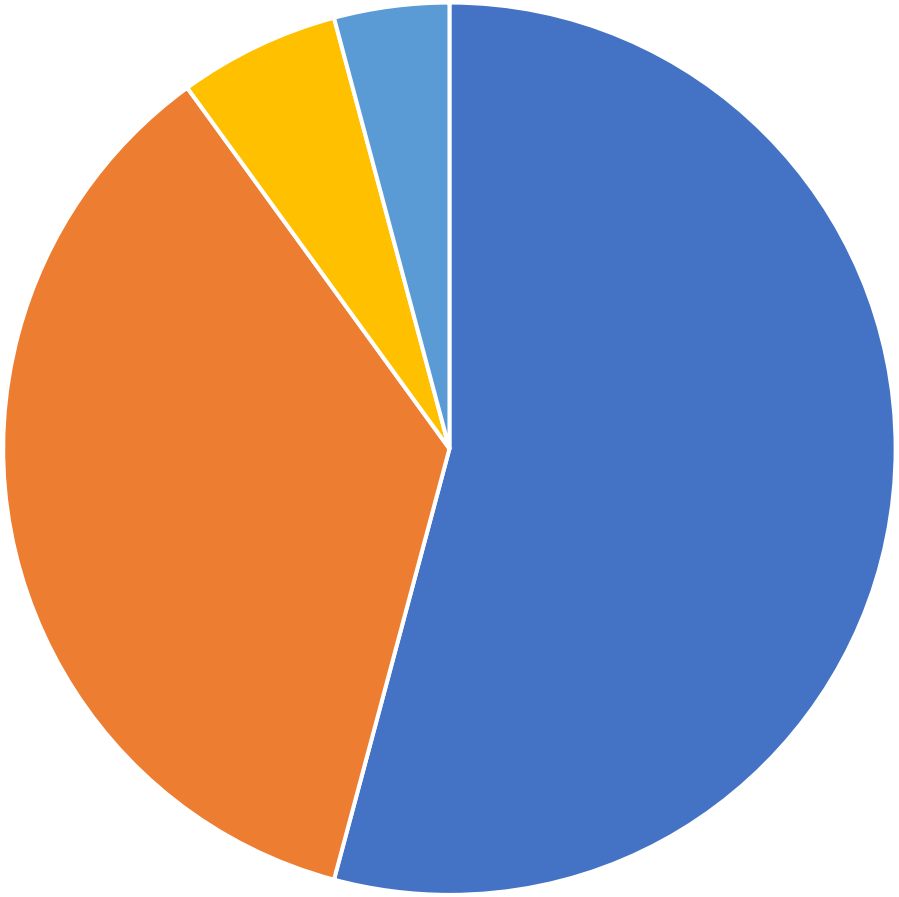
- What is “baseline?” – Do you “decrease” or “increase” relative to other segments
  - Each condition was evaluated for a mission segment that appeared “most similar” and adjustments were applied for other segments accordingly

- Severity of condition is not considered – Many conditions, especially musculoskeletal, may not change incidence but may become more severe (i.e. BC/WC percentages should change)

Output

- Very few conditions have adjustments based on segment
- Of those that could be adjusted, most are unlikely to require significant adjustment
- Data is very unlikely to be present in the literature to quantify segment adjustments

Output



No Change	Slight change almost no impact	We may want to review	We should review but have the data
54%	36%	6%	4%

Output

- Of the conditions that are recommended for review, 75% are musculoskeletal conditions (i.e. sprain/strain, fractures, etc.)
  - These are conditions that are likely gravity related, and their incidence is difficult to calculate because gravity-well/lunar habitat/EVA/Rover operations all may represent significant increases in incidence over micro-gravity operations

Output

- Remaining 25% of recommended conditions occur rapidly on earth and trapped crew (in an EVA suit or on a rover) will increase medical risk

Lessons Learned

- Performing a semi-quantitative assessment (the majority of medical risks have either never occurred in spaceflight or have happened so rarely that it was not helpful) on medical risk is difficult

Expert Elicitation - Defined

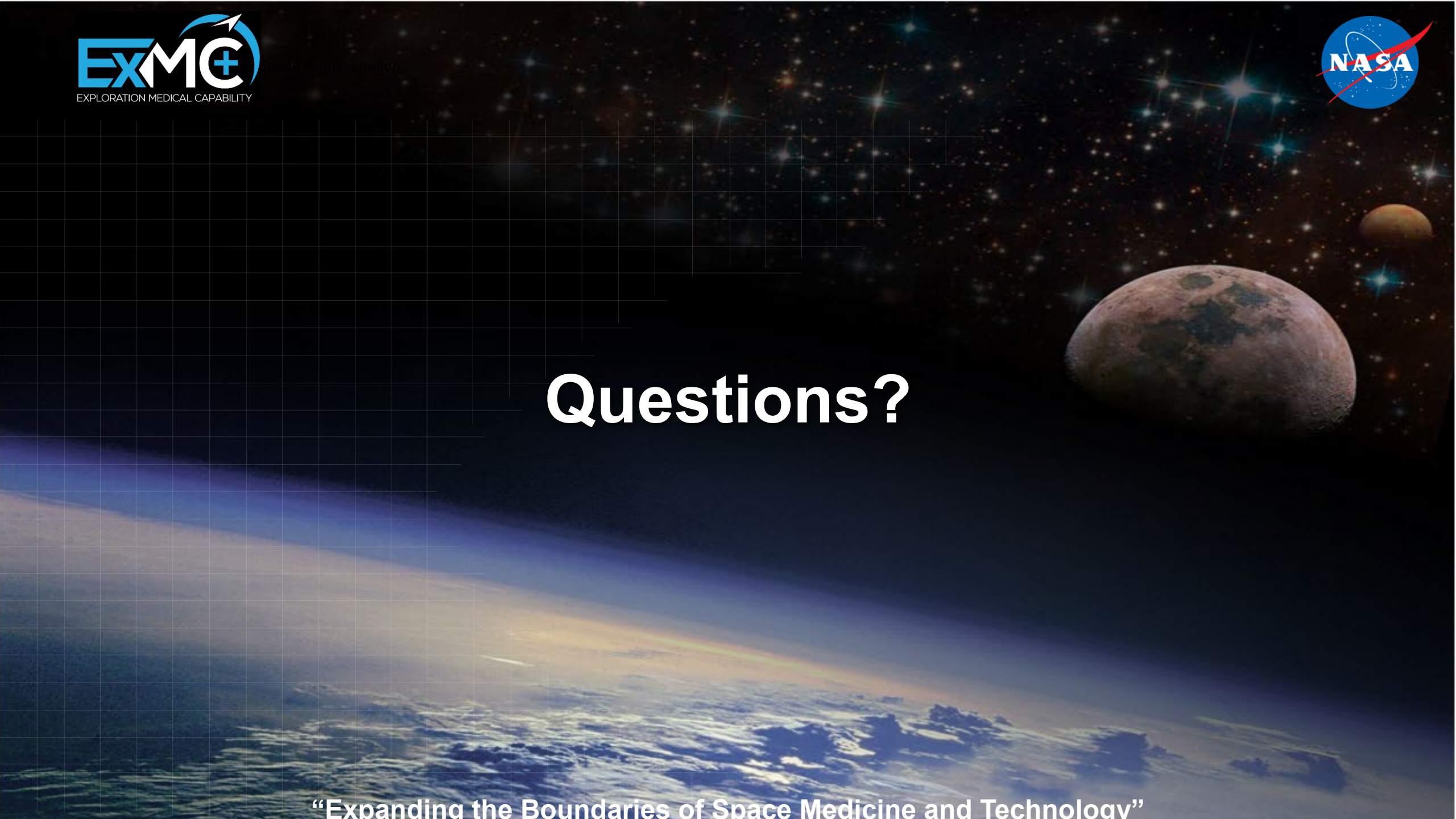
- Following a similar model to gathering the ICL (Evidence Library), a Subject Matter Expert Elicitation is a process whereby predictions can be made about risks with little evidence.

Lessons Learned – Expert Elicitation

1. Screen tasks for relevance and need to perform an elicitation (largely completed)
2. Select Panel for elicitation
   - ExMC and Ops clinicians may be considered
3. Determine what variables to consider (i.e. Incidence, BC/WC probability, RTDC, LOCL, etc.)
4. Create survey for evaluation
5. Survey panel
6. Statistical evaluation of results
7. Interpretation of findings

Expert Elicitation - Pilot Plan

- Select the “worst case” conditions for evaluation (probably going to select from the conditions for which we have no knowledge and cover more than one area of medicine)
- Create survey to evaluate segment impacts for the condition
- Request panel participation and evaluation of condition
- Review the impact on outcomes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